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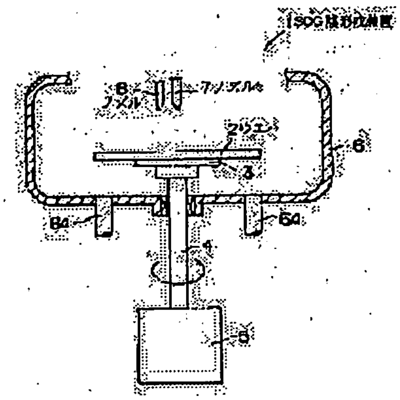
(54) METHOD AND APPARATUS FOR DEPOSITING INSULATING FILM IN SEMICONDUCTOR DEVICE

(57)Abstract:

PURPOSE: To flatten the surface of an insulating film, e.g. a layer insulating film or a surface protective film, more smoothly.

CONSTITUTION: An apparatus 1 for depositing an SOG film while rotating a wafer 2 is provided with a nozzle 8 for dripping liquid nitrogen N2 as well as a nozzle for dripping a solution forming an insulating film. Immediately before depositing the SOG film, liquid nitrogen N2 is dripped and a power source 5 is driven to rotate the wafer 2. Consequently, the surface of the wafer 2 is spin coated 'with liquid nitrogen N2.



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CLAIMS

[Claim(s)]

[Claim 1] The insulator layer formation approach of the semiconductor device characterized by carrying out rotation spreading of the liquefied cooling agent on a wafer front face just before carrying out rotation spreading of the solution for insulator layer formation.

[Claim 2] The insulator layer formation approach of a semiconductor device according to claim 1 that said liquefied cooling agent is liquid nitrogen.

[Claim 3] Insulator layer formation equipment of the semiconductor device characterized by having the rotation driving means which rotates a wafer in that horizontal plane, a liquefied cooling agent dropping means by which a liquefied cooling agent is dropped at said wafer front face in the condition of having been held at this rotation driving means, and a solution dropping means for insulator layer formation by which the solution for insulator layer formation is dropped at said wafer front face in the condition of having been held at said rotation driving means.

[Claim 4] Insulator layer formation equipment of the semiconductor device according to claim 3 said whose liquefied cooling agent is liquid nitrogen.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] Regardless of the irregularity of a substrate, an insulator layer front face is made to be made as for this invention to flatness more especially about the formation approach of an insulator layer and formation equipment used as the interlayer insulation film of a semiconductor device, or a surface protective coat.

[0002]

[Description of the Prior Art] As a conventional method of attaining flattening, as the front face of an insulator layer (for example, SiO_2 film) used as the interlayer insulation film of a semiconductor device

or a surface protective coat is not influenced if possible of the irregularity of the substrate, there is the so-called SOG (Spin-on-Glass). Namely, with SOG, the solution (Si4 (OH)) which forms an insulator layer behind is dropped at the abbreviation core of a wafer. Generate a centrifugal force and a wafer front face is made to diffuse a solution by rotating a wafer in the condition. Heat at about 400 degrees C after that, and it is made to react to the condition Si(OH) 4 ->SiO2+H2 O, and is a wafer front face SiO2 If rotation spreading of the solution which covers with the film and has a fluidity is carried out Since a solution seldom adheres to the heights on the front face of a wafer while a solution enters the crevice on the front face of a wafer, regardless of the irregularity of a substrate, flattening on the front face of an insulator layer is attained. Thereby, when for example, the upper wiring was formed on the insulator layer, probabilities, such as an open circuit, were able to be reduced and the product yield etc. was able to be improved.

[0003] Here, it is Si (OH)4 as a solution for insulator layer formation. When using, this solution reacts easily also in ordinary temperature (about 23 degrees C), and it is SiO2. Since it will be generated and the fluidity will be lost, refrigeration preservation of the solution was carried out at about 5 degrees C just before use. And since this solution is difficult to form a thin film at the temperature at the time of the refrigeration preservation for suppressing a reaction although there is a property in which viscosity becomes high with the rise of temperature when viscosity is very low and rotation spreading is performed with the condition that that viscosity is very low, it is returned to a room temperature at the time of use, and since it comes to have a certain amount of viscosity, it is made to carry out rotation spreading.

[0004]

[Problem(s) to be Solved by the Invention] However, it is difficult to fill both the embedding of the crevice of a substrate and flattening on the front face of an insulator layer to coincidence as it is impossible to make an insulator layer front face flat completely, especially detailed-ization progresses and an aspect ratio becomes high, even if it is the conventional approach which was mentioned above.

[0005] Moreover, the adhesion of the insulator layer and substrate film which were applied on it fell according to the surface state of a substrate, the interlayer insulation film exfoliated at the time of heat treatment in a back process etc., and it had also become one factor which causes aggravation of the product yield. This invention is made paying attention to the trouble of these versatility, can make an insulator layer front face flatness more, and aims at offering the insulator layer formation approach and insulator layer formation equipment of a semiconductor device which can moreover also expect the reforming effectiveness on the front face of a substrate.

[0006]

[Means for Solving the Problem] In order to attain the above-mentioned purpose, it was presupposed on the wafer front face just before carrying out rotation spreading of the solution for insulator layer formation that rotation spreading of the liquefied cooling agent is carried out to the insulator layer formation approach of the semiconductor device concerning claim 1. Moreover, invention concerning claim 2 applied liquid nitrogen as said liquefied cooling agent in invention concerning above-mentioned claim 1.

[0007] On the other hand, the insulator layer formation equipment of the semiconductor device applied to claim 3 in order to attain the above-mentioned purpose was equipped with the rotation driving means which rotates a wafer in that horizontal plane, a liquefied cooling agent dropping means to by_which a liquefied cooling agent is dropped at said wafer front face in the condition were held at this rotation driving means, and a solution dropping means for insulator layer formation to by_which the solution for insulator layer formation is dropped at said wafer front face in the condition were held at said rotation driving means.

[0008] And invention concerning claim 4 applied liquid nitrogen in invention concerning above-mentioned claim 3 as a liquefied cooling agent which a liquefied cooling agent dropping means trickles into a wafer front face.

[0009]
[Function] While comparatively a lot of liquefied cooling agents will enter the crevice on the front face of a wafer if it is in invention concerning claim 1, and rotation spreading of the liquefied cooling agent is carried out, a liquefied cooling agent does not remain in the heights on the front face of a wafer so much, and since heights will be heated compared with a crevice by friction with the air accompanying rotation of a wafer, the temperature on the front face of a wafer becomes [in a crevice] it is low and high at heights.
[0010] then, Si (OH) mentioned above, for example when rotation spreading of the solution for insulator layer formation was carried out in such the condition -- four If it is a solution [like], since viscosity will become high with the rise of temperature, the direction of the crevice where temperature is low has a high fluidity, and since the direction of heights with high temperature becomes [viscosity] high, a solution flows so that it may enter in a crevice from a heights front face. Consequently, the front face of the insulator layer generated behind becomes flatness more.
[0011] And if a wafer front face is cooled, even if a wafer front face is polluted with carbon etc., for example and the surface state is changing from the hydrophilic property to hydrophobicity, freezing removal of the hydrophobic surface part will be carried out, and the surface state of a wafer will return to a hydrophilic property. Like invention which relates to claim 2 especially, since it is an extremely stable cooling agent, it does not have a bad influence to the solution for insulator layer formation, and if liquid nitrogen is applied as a liquefied cooling agent, if a wafer front face is fully cooled by liquid nitrogen, freezing removal of the surface part of a wafer which was mentioned above will be carried out, and the surface state of a wafer will revert.
[0012] Here, invention concerning claim 3 and claim 4 is invention about a suitable manufacturing installation to realize invention concerning the manufacture approach concerning above-mentioned claim 1 and claim 2. Therefore, each operation of invention concerning claim 3 and claim 4 is substantially [as an operation of invention concerning above-mentioned claim 1 and claim 2] the same. That is, if it is in invention concerning claim 3, it has a liquefied cooling agent dropping means and two kinds of dropping means of the solution dropping means for insulator layer formation. And the actuation procedure of the manufacturing installation concerning this claim 3 trickles a liquefied cooling agent into a wafer front face with a liquefied cooling agent dropping means first, by the rotation driving means, rotates a wafer and diffuses a liquefied cooling agent all over a wafer. Subsequently, the solution for insulator layer formation is dropped at an upper front face with the solution dropping means for insulator layer formation, by the rotation driving means, a wafer is rotated and the solution for insulator layer formation is diffused all over a wafer. Consequently, the same operation as invention concerning above-mentioned claim 1 is acquired. Moreover, if it is invention concerning claim 4, the same operation as invention concerning above-mentioned claim 2 will be acquired.
[0013]
[Example] Hereafter, the example of this invention is explained based on a drawing. Drawing 1 is the sectional view showing the outline configuration of the SOG film formation equipment 1 as insulator layer formation equipment of the semiconductor device in one example of this invention. Namely, the wafer maintenance base 3 which this SOG film formation equipment 1 carries out vacuum adsorption of the rear face of the wafer 2 which is a silicon substrate, and holds this horizontally, The revolving shaft 4 which is connected centering on the rear face of this wafer maintenance base 3, and is extended caudad and which can be rotated, the source 5 of power which gives rotation driving force to this revolving shaft 4, the cup 6 which drainage-tube 6a is connected to a base, and surrounds the perimeter of the wafer maintenance base 3, and two nozzles 7 and 8 which counter the surface core of the wafer 2 in the condition of having been held on the wafer maintenance base 3, from the upper part -- since -- it is constituted.
[0014] It is a nozzle to drop the solution (for example, Si4 (OH)) which used the silicon compound as the principal component as a solution for insulator layer formation for one [among two nozzles 7 and 8]

nozzle 7 to form the SOG film here on a wafer 2, and the other end side which is not illustrated is the solution (OH) Si 4 of a room temperature condition. It connects with the source of supply which carries out specified quantity supply. Moreover, the nozzle 8 of another side is the liquid nitrogen N2 as a liquefied cooling agent. It is a nozzle for being dropped on a wafer 2, and the other end side which is not illustrated is connected to other sources of supply which carry out specified quantity supply of the liquid nitrogen.

[0015] And this SOG film formation equipment 1 is used as follows. That is, as shown in drawing 2 (a), the wafer 2 with which thin silicon oxide 10 was formed in the front face, the circuit pattern 11 used as lower layer wiring of multilayer-interconnection structure which consists of an aluminum system alloy, for example was formed on the silicon oxide 10, and the thin plasma oxidation film 12 was further formed on it is held on the wafer maintenance base 3 of SOG film formation equipment 1.

[0016] Subsequently, a nozzle 8 to liquid nitrogen N2 It is dropped at wafer 2 front face, and the source 5 of power is made to drive after the dropping, the wafer maintenance base 3 is made into a rotation condition, the wafer 2 held at it is rotated in a horizontal plane, and the liquid nitrogen dropped at a part for the core of a wafer 2 is diffused outside from a part for a core according to the centrifugal force by rotation of a wafer 2. That is, wafer 2 front face is made to carry out rotation spreading of the liquid nitrogen first within SOG film formation equipment 1.

[0017] Since the viscosity of liquid nitrogen is very small at this time, liquid nitrogen enters in the crevice of the irregularity formed with the circuit pattern 11 (refer to drawing 2 (b)). Since the liquid nitrogen adhering to the heights front face formed with the circuit pattern 11 is blown away to the inside of a crevice being cooled quickly by friction with an ambient atmosphere It is not quickly cooled like [in a crevice] and a heights front face is rather heated by the frictional heat by friction between ambient atmospheres.

[0018] Consequently, between the crevice formed with the circuit pattern 11, and heights, the temperature gradient from which the direction of a crevice serves as low temperature will arise. Then, suspend rotation of the wafer maintenance base 3 and a solution (OH) Si 4 is dropped at wafer 2 front face from a nozzle 7. the solution Si (OH) which is made to drive the source 5 of power again after the dropping, makes the wafer maintenance base 3 a rotation condition, is made to rotate the wafer 2 held at it in a horizontal plane, and is dropped at a part for the core of a wafer 2 -- four You make it spread outside from a part for a core according to the centrifugal force by rotation of a wafer 2. That is, rotation spreading of liquid nitrogen is followed within the SOG film formation equipment 1 of this example, and it is a solution (OH) Si 4. Rotation spreading is performed.

[0019] Here, they are the skin temperature of a wafer 2, and a solution (OH) Si 4. The relation with viscosity has the relation to which viscosity becomes high with the rise of skin temperature (that is, a fluidity becomes small), as shown in drawing 3 . Moreover, solution Si 4 (OH) As for a void incidence rate, viscosity and the relation with a void (air bubbles) incidence rate have the relation it is high unrelated, so that viscosity is high, as shown in drawing 4 (a). In addition, with void incidence-rate V (%), as shown in drawing 4 (b), when thickness for a and a crevice is set to b for the thickness for heights of a circuit pattern 11, it asks as V=(1-b/a) x100. However, height h of the heights of a circuit pattern 11 is 0.5 micrometers, and the width of face of 1.0 micrometers and a crevice is [the result shown in drawing 4 (a)] the TOKYO OHKA KOGYO CO., LTD. make and OCD-Type7 as a solution for insulator layer formation. It is a thing at the time of using 12000-T (trade name).

[0020] That is, solution Si 4 (OH) The fluidity becomes high, so that it is low temperature, and the incidence rate of a void becomes low, so that the fluidity of a solution is high. When why the incidence rate of this void becomes low is explained further in full detail, in the case of rotation spreading of a solution (OH) Si 4 Si4 which flowed in in the crevice since a temperature gradient which was mentioned above had arisen between the irregularity of a circuit pattern 11 (OH) Since it does not change to a solid-state ahead of heights Solution Si 4 (OH) As shown in drawing 5 , it will flow so that the interior of the crevice where temperature is low may be entered from the heights front face where temperature is

high. And it is suitably heated at an annealing furnace after that, the reaction Si(OH) 4 ->SiO2+H2 O arises, and it is SiO2. Since the film is formed, as shown in drawing 2 (c), regardless of the irregularity of the circuit pattern 11 of a substrate, the SOG film 13 with a very flat front face is formed. On the other hand, since it enters in a crevice from the solution dropped [that the inside of a crevice continues being ordinary temperature, and] first, before the inside of a crevice is buried completely, the above-mentioned reaction arises, and it is SiO2. Since the film will be formed, an SOG film front face cannot be made flat enough.

[0021] Thus, if it is in this example, the irregularity of the circuit pattern 11 of a substrate and the configuration of the front face of the SOG film 13 can be made unrelated to abbreviation completeness, and even if it is the case that especially the aspect ratio of a circuit pattern 11 is large, SOG film 13 front face can be made flat. Incidentally, according to this invention person's view, the embedding of a tooth space 0.20 micrometers or less also becomes possible.

[0022] Then, as shown in drawing 2 (a), step coverage nature will thicken thickness of the plasma oxidation film 12 which is not enough, and the aspect ratio of a circuit pattern 11 may be made small. And the advantage that that thickness of the plasma oxidation film 12 can be thickened can make large more the process margin of the etchback performed behind will be yielded.

[0023] Furthermore, liquid nitrogen N2 which was excellent in stability if it was in this example Since it uses, especially a bad influence is not produced. It is O2 even when the surface state changes from a hydrophilic property to hydrophobicity, since the contamination layer 14 (for example, contamination layer of the carbon system which may be produced at the time of conveyance of a wafer 2 etc.) as shown in the front face of the plasma oxidation film 12 at drawing 6 arose rather. There is an advantage that a surface state can be restored to a hydrophilic property without performing special surface treatment, such as a plasma exposure and UV irradiation.

[0024] That is, the contamination layer 14 is the low-temperature (-196 degrees C) liquid nitrogen N2 very much. If immersed, since the hydrophilic component of the contamination layer 14 bottom will freeze over, it is liquid nitrogen N2. Since the contamination layer 14 exfoliates from the part which froze over at the time of rotation spreading, the surface of the plasma oxidation film 12 excellent in the hydrophilic property expresses just before SOG film 13 membrane formation. Thereby, the adhesive strength in the interface of the SOG film 13 and the plasma oxidation film 12 increases, and exfoliation between these film can be prevented.

[0025] Here, a rotation driving means is constituted by the wafer maintenance base 3, a revolving shaft 4, and the source 5 of power, a liquefied cooling agent dropping means is constituted by a nozzle 8 and other sources of supply which are not illustrated, and the solution dropping means for insulator layer formation is constituted from this example by a nozzle 7 and the source of supply which is not illustrated. In addition, although the above-mentioned example explained the case where this invention was applied to the process which forms the SOG film 13 as an interlayer insulation film, you may be the process which is not limited to this and forms the insulator layer as a surface protective coat.

[0026] Moreover, at the above-mentioned example, it is liquid nitrogen N2 as a liquefied cooling agent. Although the case where it used was explained, it is not limited to this and liquid helium helium may be applied, for example, it is liquid nitrogen N2. And it does not matter even if it uses liquid helium helium together. Furthermore, although [the above-mentioned example] an annealing furnace is used for heating just before forming the SOG film 13, not only this but lamp heating, heater heating, microwave heating, etc. may be applied and used together.

[0027]

[Effect of the Invention] As explained above, while being able to write carrying out rotation spreading of the liquefied cooling agent and being able to make the front face of an insulator layer very flat, according to invention concerning claim 1, the effectiveness that a contamination layer is removable is shown in a wafer front face just before carrying out rotation spreading of the solution for insulator layer formation, without performing special surface treatment.

[0028] Since the liquid nitrogen excellent in stability was used when it was invention concerning especially claim 2, since it is low temperature very much, it is also effective in a contamination layer being certainly removable to produce especially a bad influence. And if it is invention concerning claim 3 and claim 4, it is effective in the ability to carry out suitably invention concerning above-mentioned claim 1 and claim 2 by carrying out rotation spreading of the liquefied cooling agent first.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the sectional view showing the configuration of one example of this invention.
[Drawing 2] It is a sectional view for explaining an operation of an example.
[Drawing 3] It is a graph showing the relation between the skin temperature of a wafer, and the viscosity of a solution.
[Drawing 4] It is drawing explaining the relation between the viscosity of a solution, and the incidence rate of a void.
[Drawing 5] It is an expanded sectional view for explaining an operation of an example in full detail.
[Drawing 6] It is an expanded sectional view for explaining other operations of an example.
[Description of Notations]
1 SOG Film Formation Equipment (Insulator Layer Formation Equipment of Semi-conductor)
2 Wafer
3 Wafer Maintenance Base
4 Revolving Shaft
5 Source of Power
7 Eight Nozzle
10 Thin Oxide Film
11 Circuit Pattern
12 Plasma Oxidation Film
13 SOG Film (Insulator Layer)
14 Contamination Layer
N2 Liquid nitrogen (liquefied cooling agent)
Si4 (OH) Solution for insulator layer formation

[Translation done.]

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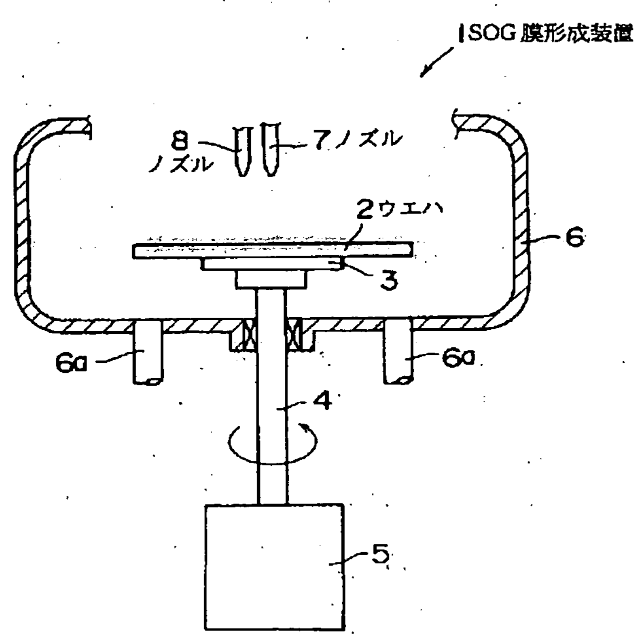
(54)【発明の名称】　半導体装置の絶縁膜形成方法及び絶縁膜形成装置

(57)【要約】
【目的】層間絶縁膜や表面保護膜となる絶縁膜の表面を、より平坦化できるようにする。
【構成】ウエハ２を回転させることによりＳＯＧ膜を形成するＳＯＧ膜形成装置１に、絶縁膜形成用溶液を滴下するノズル７の他に、液体窒素N_2を滴下するノズル８を設ける。そして、ＳＯＧ膜を形成する直前に、液体窒素N_2を滴下し動力源５を駆動させてウエハ２を回転させることにより、その液体窒素N_2をウエハ２表面に回転塗布させる。



【特許請求の範囲】

【請求項１】　絶縁膜形成用溶液を回転塗布する直前のウエハ表面に、液状冷却剤を回転塗布することを特徴とする半導体装置の絶縁膜形成方法。

【請求項２】　前記液状冷却剤が液体窒素である請求項１記載の半導体装置の絶縁膜形成方法。

【請求項３】　ウエハをその水平面内で回転させる回転駆動手段と、この回転駆動手段に保持された状態の前記ウエハ表面に液状冷却剤を滴下する液状冷却剤滴下手段と、前記回転駆動手段に保持された状態の前記ウエハ表面に絶縁膜形成用溶液を滴下する絶縁膜形成用溶液滴下手段と、を備えたことを特徴とする半導体装置の絶縁膜形成装置。

【請求項４】　前記液状冷却剤が液体窒素である請求項３記載の半導体装置の絶縁膜形成装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】この発明は、半導体装置の層間絶縁膜や表面保護膜となる絶縁膜の形成方法及び形成装置に関し、特に、下地の凹凸に関係なく絶縁膜表面をより平坦にできるようにしたものである。

【０００２】

【従来の技術】半導体装置の層間絶縁膜や表面保護膜となる絶縁膜（例えば、SiO_2 膜）の表面を、その下地の凹凸の影響をなるべく受けないようにして平坦化を図る従来の方法としては、所謂ＳＯＧ（Spin-on-Glass ）がある。即ち、ＳＯＧとは、後に絶縁膜を形成する溶液（Ｓｉ（ＯＨ）４ ）をウエハの略中心部に滴下し、その状態でウエハを回転させることにより遠心力を発生させて溶液をウエハ表面に拡散させ、その後に４００℃程度に加熱し、$Si(OH)_4 \rightarrow SiO_2 + H_2O$ という具合に反応させてウエハ表面を SiO_2 膜で被覆するものであり、流動性を有する溶液を回転塗布させると、ウエハ表面の凹部には溶液が入り込む一方で、ウエハ表面の凸部にはあまり溶液が付着しないから、下地の凹凸に関係なく、絶縁膜表面の平坦化が図られるのである。これにより、その絶縁膜上に例えば上層配線を形成する場合に、断線等の確率を低減して製品歩留り等を向上することができたのである。

【０００３】ここで、絶縁膜形成用の溶液として $Si(OH)_4$ を用いる場合、かかる溶液は常温（２３℃程度）でも容易に反応して SiO_2 が生成されその流動性が失われてしまうことから、使用直前までその溶液は５℃程度で冷蔵保存されていた。そして、この溶液は、温度の上昇に伴って粘度が高くなる性質があるが、反応を抑えるための冷蔵保存時の温度では極めて粘度が低く、その粘度が極めて低い状態のまま回転塗布を行った場合に薄膜を形成することが困難であることから、使用時には室温に戻し、ある程度の粘度を有するようになってから回転塗布を行うようにしていた。

【０００４】

【発明が解決しようとする課題】しかしながら、上述したような従来の方法であっても、絶縁膜表面を完全に平坦にすることは不可能であり、特に微細化が進みアスペクト比が高くなるに従って、下地の凹部の埋め込みと、絶縁膜表面の平坦化との両方を同時に満たすことが困難になっている。

【０００５】また、下地の表面状態により、その上に塗布された絶縁膜と下地膜との密着性が低下し、後工程における熱処理時等に層間絶縁膜が剥離してしまい、製品歩留りの悪化を招く一要因ともなっていた。本発明は、これら種々の問題点に着目してなされたものであって、絶縁膜表面をより平坦にすることができ、しかも下地表面の改質効果をも期待できる半導体装置の絶縁膜形成方法及び絶縁膜形成装置を提供することを目的としている。

【０００６】

【課題を解決するための手段】上記目的を達成するために、請求項１に係る半導体装置の絶縁膜形成方法は、絶縁膜形成用溶液を回転塗布する直前のウエハ表面に、液状冷却剤を回転塗布することとした。また、請求項２に係る発明は、上記請求項１に係る発明における前記液状冷却剤として、液体窒素を適用した。

【０００７】一方、上記目的を達成するために、請求項３に係る半導体装置の絶縁膜形成装置は、ウエハをその水平面内で回転させる回転駆動手段と、この回転駆動手段に保持された状態の前記ウエハ表面に液状冷却剤を滴下する液状冷却剤滴下手段と、前記回転駆動手段に保持された状態の前記ウエハ表面に絶縁膜形成用溶液を滴下する絶縁膜形成用溶液滴下手段と、を備えた。

【０００８】そして、請求項４に係る発明は、上記請求項３に係る発明において、液状冷却剤滴下手段がウエハ表面に滴下する液状冷却剤として、液体窒素を適用した。

【０００９】

【作用】請求項１に係る発明にあっては、液状冷却剤が回転塗布されると、ウエハ表面の凹部には比較的多量の液状冷却剤が入り込む一方、ウエハ表面の凸部にはそれほど液状冷却剤が残らないし、凸部はウエハの回転に伴う空気との摩擦により凹部に比べて加熱されることになるから、ウエハ表面の温度は、凹部で低く凸部で高くなる。

【００１０】すると、そのような状態で絶縁膜形成用の溶液が回転塗布されると、例えば上述した $Si(OH)_4$ のような溶液であれば、温度の上昇に伴って粘度が高くなることから、温度の低い凹部の方が流動性が高く、温度の高い凸部の方が粘度が高くなるため、溶液は、凸部表面から凹部内に入り込むように流動する。その結果、後に生成される絶縁膜の表面がより平坦になる。

【００１１】そして、ウエハ表面を冷却すると、例えば

ウエハ表面がカーボン等によって汚染されて表面状態が親水性から疎水性に変化していても、その疎水性の表層部分が氷結除去され、ウエハの表面状態が親水性に戻る。特に、請求項２に係る発明のように、液状冷却剤として液体窒素が適用されると、安定性の高い冷却剤であることから、絶縁膜形成用の溶液に対して悪影響を与えないし、液体窒素によってウエハ表面が充分に冷却されれば、上述したようなウエハの表層部分が氷結除去され、ウエハの表面状態が復元する。

【００１２】ここで、請求項３及び請求項４に係る発明は、上記請求項１，請求項２に係る製造方法に係る発明を実現するのに好適な製造装置に関する発明である。従って、請求項３，請求項４に係る発明のそれぞれの作用は、上記請求項１，請求項２に係る発明の作用と実質的に同じである。即ち、請求項３に係る発明にあっては、液状冷却剤滴下手段と、絶縁膜形成用溶液滴下手段という二種類の滴下手段を有している。そして、この請求項３に係る製造装置の作動手順は、先ず液状冷却剤滴下手段によって液状冷却剤をウエハ表面に滴下し、回転駆動手段によってウエハを回転させて液状冷却剤をウエハ全面に拡散させる。次いで、絶縁膜形成用溶液滴下手段によって絶縁膜形成用溶液を上表面に滴下し、回転駆動手段によってウエハを回転させて絶縁膜形成用溶液をウエハ全面に拡散させる。この結果、上記請求項１に係る発明と同様の作用が得られる。また、請求項４に係る発明であれば、上記請求項２に係る発明と同様の作用が得られる。

【００１３】

【実施例】以下、この発明の実施例を図面に基づいて説明する。図１は、本発明の一実施例における半導体装置の絶縁膜形成装置としてのＳＯＧ膜形成装置１の概略構成を示す断面図である。即ち、このＳＯＧ膜形成装置１は、シリコン基板であるウエハ２の裏面を真空吸着してこれを水平に保持するウエハ保持台３と、このウエハ保持台３の裏面中心に連結され下方に伸びる回転自在の回転軸４と、この回転軸４に回転駆動力を付与する動力源５と、底面に排液管６ａが接続されウエハ保持台３の周囲を包囲するカップ６と、ウエハ保持台３に保持された状態のウエハ２の表面中心部に上方から対向する二つのノズル７，８と、から構成されている。

【００１４】ここで、二つのノズル７，８のうち、一方のノズル７は、ＳＯＧ膜を形成するための絶縁膜形成用溶液として、シリコン化合物を主成分とした溶液（例えば、Ｓｉ（ＯＨ）$_4$）をウエハ２上に滴下するためのノズルであり、その図示しない他端側は、室温状態の溶液Ｓｉ（ＯＨ）$_4$ を所定量供給する供給源に接続されている。また、他方のノズル８は、液状冷却剤としての液体窒素N_2 をウエハ２上に滴下するためのノズルであって、その図示しない他端側は、液体窒素を所定量供給する他の供給源に接続されている。

【００１５】そして、このＳＯＧ膜形成装置１は、以下のように使用される。即ち、図２（ａ）に示すように、表面に薄いシリコン酸化膜１０が形成され、そのシリコン酸化膜１０上に多層配線構造の下層配線となる例えばアルミニウム系合金からなる配線パターン１１が形成され、さらにその上に薄いプラズマ酸化膜１２が形成されたウエハ２を、ＳＯＧ膜形成装置１のウエハ保持台３に保持する。

【００１６】次いで、ノズル８から液体窒素N_2 をウエハ２表面に滴下し、その滴下の後に動力源５を駆動させてウエハ保持台３を回転状態とし、それに保持されたウエハ２を水平面内で回転させて、ウエハ２の中心部分に滴下されている液体窒素を、ウエハ２の回転による遠心力によって中心部分から外側に拡散させる。つまり、ＳＯＧ膜形成装置１内では、先ず液体窒素をウエハ２表面に回転塗布させる。

【００１７】この時、液体窒素の粘性は極めて小さいことから、配線パターン１１によって形成された凹凸の凹部内に液体窒素が入り込み（図２（ｂ）参照）、凹部内は急速に冷却されるのに対し、配線パターン１１によって形成された凸部表面に付着した液体窒素は雰囲気との摩擦によって吹き飛ばされるので、凹部内のように急速に冷却されることはなく、むしろ凸部表面は、雰囲気との間の摩擦による摩擦熱によって加熱される。

【００１８】この結果、配線パターン１１によって形成された凹部及び凸部間には、凹部の方が低温となる温度差が生じることになる。その後、ウエハ保持台３の回転を一旦停止しノズル７から溶液Ｓｉ（ＯＨ）$_4$をウエハ２表面に滴下し、その滴下の後に再び動力源５を駆動させてウエハ保持台３を回転状態とし、それに保持されたウエハ２を水平面内で回転させて、ウエハ２の中心部分に滴下されている溶液Ｓｉ（ＯＨ）$_4$ を、ウエハ２の回転による遠心力によって中心部分から外側に拡散させる。つまり、本実施例のＳＯＧ膜形成装置１内では、液体窒素の回転塗布に続いて、溶液Ｓｉ（ＯＨ）$_4$ の回転塗布が行われる。

【００１９】ここで、ウエハ２の表面温度と、溶液Ｓｉ（ＯＨ）$_4$ の粘度との関係は、図３に示すように、表面温度の上昇に伴って粘度が高くなる（つまり流動性が小さくなる）関係にある。また、溶液Ｓｉ（ＯＨ）$_4$ の粘度と、ボイド（気泡）発生率との関係は、図４（ａ）に示すように、粘度が高いほど、ボイド発生率が高くなる関係にある。なお、ボイド発生率Ｖ（％）とは、図４（ｂ）に示すように、配線パターン１１の凸部分の膜厚をａ、凹部分の膜厚をｂとした場合に、

Ｖ＝（１－ｂ／ａ）×１００

として求められる。ただし、図４（ａ）に示す結果は、配線パターン１１の凸部の高さｈが1.０μｍ、凹部の幅が0.５μｍであり、絶縁膜形成用溶液として、東京応化工業社製、ＯＣＤ－Ｔｙｐｅ７　１２０００－Ｔ（商品

名）を使用した場合のものである。

【００２０】つまり、溶液Ｓｉ（ＯＨ）$_4$ は低温であるほどその流動性が高くなり、溶液の流動性が高いほどボイドの発生率は低くなるのである。このボイドの発生率が低くなる理由をさらに詳述すると、溶液Ｓｉ（ＯＨ）$_4$の回転塗布の際には、配線パターン１１の凹凸間には上述したような温度差が生じているため、凹部内に流れ込んだＳｉ（ＯＨ）$_4$ が凸部よりも先に固体に変化することがないので、溶液Ｓｉ（ＯＨ）$_4$ は、図５に示すように、温度の高い凸部表面から、温度の低い凹部内部に入り込むように流動することになる。そして、その後にアニール炉で適宜加熱されてＳｉ（ＯＨ）$_4$ →ＳｉＯ$_2$ ＋Ｈ$_2$ Ｏという反応が生じてＳｉＯ$_2$ 膜が形成されるため、下地の配線パターン１１の凹凸に関係なく、図２（ｃ）に示すように、表面が極めて平坦なＳＯＧ膜１３が形成されるのである。これに対し、凹部内が常温のままであると、最初に滴下された溶液から凹部内に入り込むことから、凹部内が完全に埋まる前に上記反応が生じてＳｉＯ$_2$ 膜が形成されてしまうので、ＳＯＧ膜表面を充分に平坦にすることができないのである。

【００２１】このように、本実施例にあっては、下地の配線パターン１１の凹凸と、ＳＯＧ膜１３の表面の形状とを略完全に無関係にすることができ、特に配線パターン１１のアスペクト比が大きい場合であっても、ＳＯＧ膜１３表面を平坦にすることができる。ちなみに、本発明者の所見によれば、０．２０μｍ以下のスペースの埋め込みも可能となる。

【００２２】すると、図２（ａ）に示すように段差被覆性が充分でないプラズマ酸化膜１２の膜厚を厚くして、配線パターン１１のアスペクト比を小さくしてしまっても構わないことになる。そして、プラズマ酸化膜１２の膜厚を厚くできるということは、後に行われるエッチバックのプロセスマージンをより広くすることができるという利点を生むことになる。

【００２３】さらに、本実施例にあっては、安定性に優れた液体窒素Ｎ$_2$ を利用しているため、特に悪影響を生じることもない。むしろ、プラズマ酸化膜１２の表面に、図６に示すような汚染層１４（例えば、ウエハ２の搬送時等に生じ得るカーボン系の汚染層）が生じたために、その表面状態が親水性から疎水性に変化した場合でも、Ｏ$_2$ プラズマ照射や紫外線照射等の特殊な表面処理を行うことなく、表面状態を親水性に復元することができるという利点がある。

【００２４】即ち、汚染層１４が極めて低温（－１９６℃）の液体窒素Ｎ$_2$ に浸漬されると、汚染層１４の下側の親水成分が氷結するため、液体窒素Ｎ$_2$ の回転塗布時にその氷結した部分から汚染層１４が剥離するから、親水性に優れたプラズマ酸化膜１２の表層がＳＯＧ膜１３成膜直前に表出するのである。これにより、ＳＯＧ膜１３とプラズマ酸化膜１２との界面における接着力が高まり、それら膜間の剥離を防止することができるのである。

【００２５】ここで、本実施例では、ウエハ保持台３，回転軸４及び動力源５によって回転駆動手段が構成され、ノズル８及び図示しない他の供給源によって液状冷却剤滴下手段が構成され、ノズル７及び図示しない供給源によって絶縁膜形成用溶液滴下手段が構成される。なお、上記実施例では、層間絶縁膜としてのＳＯＧ膜１３を形成するプロセスに本発明を適用した場合について説明したが、これに限定されるものではなく、表面保護膜としての絶縁膜を形成するプロセスであっても構わない。

【００２６】また、上記実施例では、液状冷却剤として液体窒素Ｎ$_2$ を用いた場合について説明したが、これに限定されるものではなく、例えば液体ヘリウムＨｅを適用してもよいし、液体窒素Ｎ$_2$ 及び液体ヘリウムＨｅを併用しても構わない。さらに、上記実施例では、ＳＯＧ膜１３を形成する直前の加熱にアニール炉を用いるとしているが、これに限らず、ランプ加熱，ヒータ加熱，マイクロ波加熱等を適用，併用しても構わない。

【００２７】

【発明の効果】以上説明したように、請求項１に係る発明によれば、絶縁膜形成用溶液を回転塗布する直前のウエハ表面に、液状冷却剤を回転塗布することとしたため、絶縁膜の表面を極めて平坦にすることができるとともに、特殊な表面処理を行うことなく汚染層を除去することができるという効果がある。

【００２８】特に請求項２に係る発明であれば、安定性に優れた液体窒素を用いたため、特に悪影響を生じることもないし、極めて低温であるため確実に汚染層を除去することができるという効果がある。そして、請求項３，請求項４に係る発明であれば、先ず液状冷却剤を回転塗布することにより、上記請求項１，請求項２に係る発明を好適に実施することができるという効果がある。

【図面の簡単な説明】

【図１】本発明の一実施例の構成を示す断面図である。

【図２】実施例の作用を説明するための断面図である。

【図３】ウエハの表面温度と溶液の粘度との関係を表すグラフである。

【図４】溶液の粘度とボイドの発生率との関係を説明する図である。

【図５】実施例の作用を詳述するための拡大断面図である。

【図６】実施例の他の作用を説明するための拡大断面図である。

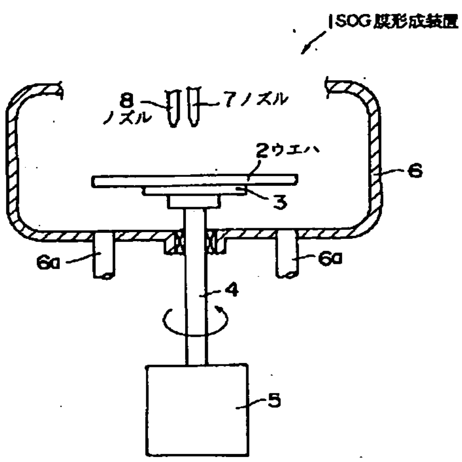
【符号の説明】

1	ＳＯＧ膜形成装置（半導体の絶縁膜形成装置）
2	ウエハ
3	ウエハ保持台
4	回転軸

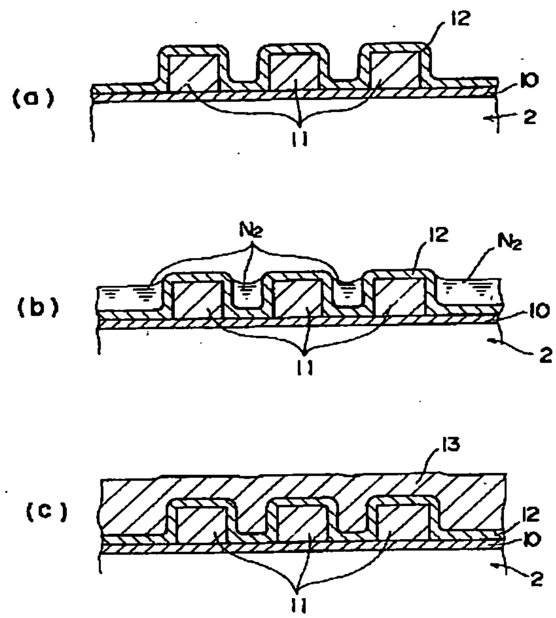
5　動力源
7，8　ノズル
10　薄い酸化膜
11　配線パターン
12　プラズマ酸化膜

13　SOG膜（絶縁膜）
14　汚染層
N_2　液体窒素（液状冷却剤）
Si（OH）$_4$　絶縁膜形成用溶液

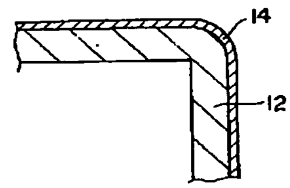
【図1】



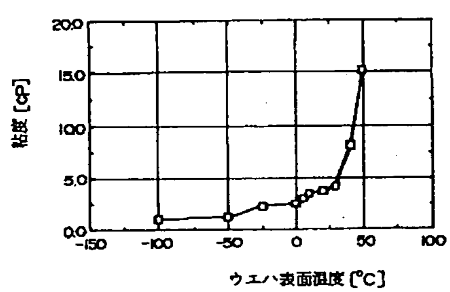
【図2】



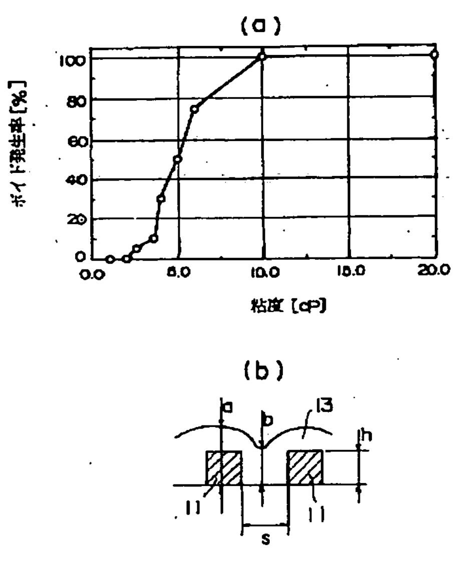
【図6】



【図3】



【図4】



【図5】